Acute type I aortic dissection: Traditional versus hybrid repair with antegrade stent delivery to the descending thoracic aorta

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Objective: We compared the short-term outcomes between patients who had undergone classic repair for type I aortic dissection and those who had undergone concomitant antegrade stenting in the descending thoracic aorta.

Methods: From January 2005 to December 2012, 112 patients were treated for acute type I aortic dissection. Eighty-seven patients (group A) underwent traditional operations on the ascending and proximal arch (n = 79, 90.8%), total arch (n = 7, 8.1%), or ascending aorta (n = 1, 1.2%). Twenty-five patients (group B) underwent ascending and proximal arch repair and antegrade stent grafting in the descending thoracic aorta. Various concomitant procedures were performed in both groups. The circulatory arrest times were similar between the 2 groups.

Results: The 30-day mortality was 13.8% (n = 12) in group A and 12% (n = 3) in group B. Nine patients in group A (10.3%) and 3 in group B (12%) experienced a postoperative stroke. In group A, 1 patients (1.5%) developed transient spinal cord ischemia, and in group B, 2 patients had transient paraparesis (8.0%). Preoperatively, 24 group A patients and 19 group B patients had malperfusion; this condition resolved postoperatively in 13 group A patients (54.2%) and 16 group B patients (84.2%; $P < .037$). Eight group A patients (10.8%) and 1 group B patient (4.5%) underwent additional postoperative procedures on the thoracoabdominal aorta a median of 776.5 days (range, 168.5-1102.0) and 54 days postoperatively, respectively.

Conclusions: Antegrade endovascular grafting of the descending thoracic aorta during repair of acute type I aortic dissection is technically safe, does not increase the circulatory arrest time, and could help patients with preoperative malperfusion. Long-term follow-up data are needed. (J Thorac Cardiovasc Surg 2014;148:119-25)

ACD

The traditional approach for treating acute type I aortic dissection consists of emergent ascending aortic replacement with open distal anastomosis with or without aortic valve or aortic root repair or replacement. Surgical treatment focuses on the ascending aorta, not the remaining dissection in the thoracoabdominal aorta. The remaining diseased portion of the aorta is managed medically. Patency of the false lumen, the extent of dissection, a more distally extended false lumen at the initial presentation, and a connective tissue disorder have been considered significant factors for aneurysmal dilatation of the descending aorta; these factors also affect the possible need for reoperation and the development of fatal rupture.[1-4] During the past decade, emerging endovascular technology has given physicians new options, including extending the traditional primary open repair of acute type I aortic dissection to include the proximal descending aorta.

In complicated acute type B or DeBakey acute type III aortic dissection, endovascular grafts are used to cover the proximal entry tear, reduce pressurization of the false lumen, treat malperfusion, and induce favorable aortic remodeling, with promising results.[5,6] Despite the availability of this treatment and others, predicting the course of thoracoabdominal aortic dissection in a given patient remains challenging. In an effort to address this issue, we evaluated antegrade stent grafting of the descending thoracic aorta (DTA) during the surgical repair of acute type I aortic dissection. We compared this hybrid procedure's intraoperative and short-term outcomes with those of traditional repair alone. Furthermore, we assessed the fate of the descending and abdominal aorta and the fate of their false lumen.

METHODS

Data were obtained from a prospectively maintained database and verified from the hospital records. The institutional review board approved the present study.

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Abbreviations and Acronyms
ACP = antegrade cerebral perfusion
CPB = cardiopulmonary bypass
CT = computed tomography
DTA = descending thoracic aorta

From January 2005 to December 2012, 112 consecutive patients underwent surgical repair of acute DeBakey type I aortic dissection at our institution. We excluded patients with DeBakey type II dissection limited to the ascending aorta or chronic dissection of the ascending aorta.

Study Design and Variables

Our analysis included 2 groups (Tables 1 and 2). Group A comprised 87 patients (63 men; median age, 57 years; range, 48-66) who had undergone traditional repair of acute type I aortic dissection. Group B comprised 25 patients (22 men; median age, 64 years; range, 48-73; $P = .20$) who had undergone both traditional repair of the proximal acute dissection and antegrade stent graft placement in the proximal DTA. Before March 2009, all patients underwent traditional surgical repair for acute type I aortic dissection. After that date, both traditional and hybrid repair with antegrade stent grafting in the DTA were performed. The choice of approach was mainly determined by the presence of preoperative malperfusion, favoring the hybrid repair primarily for patients with malperfusion, although both techniques were applied for this indication. Additionally, the distal extent of the aortic dissection (at the level of the diaphragm vs the aortic bifurcation) and evidence of aneurysmal dilatation of the proximal DTA caused us to favor the hybrid approach for patients in whom the dissection extended to the level of the diaphragm and in patients with aneurysmal disease in the proximal DTA.

Pulmonary disease was defined as a history of restrictive or obstructive lung disease. Cardiac disease was defined as coronary artery disease, previous cardiac surgery, heart failure, or arrhythmia. Connective tissue disorders included Marfan syndrome, Loeys-Dietz syndrome, familial thoracic aortic aneurysm, and genetic mutations. The following outcome variables were analyzed: operative mortality, stroke, paralysis, acute renal insufficiency, and hospitalization length. The definitions for these and the definitions of cardiopulmonary bypass (CPB) time, systemic circulatory arrest time, and myocardial ischemia time have been previously published.[7] In brief, the myocardial ischemia time extended from the initiation of circulatory arrest or crossclamp placement until clamp removal. The CPB time included the period on the heart-lung machine but not the circulatory arrest time. The systemic circulatory arrest time was the period in which the pump was off but the patient was receiving antegrade cerebral perfusion (ACP); and the total circulatory arrest time was the period with ACP and the period when the pump was turned off without ACP. In interpreting the follow-up computed tomography (CT) angiogram, a patent false lumen was defined as no evidence of thrombus formation along the entire length of the thoracoabdominal aorta; a partially thrombosed false lumen as evidence of thrombus formation in the thoracoabdominal aorta; and a thrombosed false lumen as complete thrombosis with no evidence of contrast dye within. With regard to endoleaks in group B, if contrast dye was seen in the proximal DTA and was not associated with retrograde flow from the false lumen, this was considered to indicate a type Ia endoleak. Retrograde flow into the false lumen in patients with a patent or partially thrombosed false lumen was not considered to indicate a distal or type Ib endoleak.

Our primary outcome measure was all reintervention (open or endovascular) in the descending or thoracoabdominal aorta. Secondary outcome measures included all other postoperative complications and operative mortality. Correlation of the fate of the aortic false lumen (completely thrombosed, partially thrombosed, or fully patent) with the primary outcome was also performed.

In all cases, the preoperative evaluation included CT and/or intraoperative transesophageal echocardiography before the sternotomy was performed. None of the procedures necessitated fluoroscopy or contrast administration. Just before hospital discharge, CT angiography was performed routinely unless the patient's creatinine value was elevated. Recommendations were made for performing CT angiography at 1, 3, 6, and 12 months after treatment, and, then, if the patient's condition remained stable, annually.

Surgical Technique

Group A. All patients except those in extremis underwent intraoperative transesophageal echocardiography before sternotomy. In all cases, near-infrared spectroscopy probes to monitor the cerebral perfusion pressure were placed over the cranium to measure the regional cerebral oxygen saturation. Until mid-2008, we preferred to achieve arterial inflow cannulation by way of the right axillary artery with an 8-mm end-to-side graft. From that time until the end of the study, innominate artery cannulation was our first choice for all proximal aortic operations,[7] unless specific radiologic signs (ie, propagation of the dissection into the innominate artery and its branches) or the patient's condition (ie, in extremis or hemodynamically unstable) indicated alternative inflow cannulation. An 8-mm graft was sewn to the axillary or innominate artery using a previously described technique.[7] In treating acute dissections, we do not routinely crossclamp the ascending aorta unless the heart distends on fibrillation because of severe aortic regurgitation. After CPB was initiated, we cooled the patient to 24°C. In all but 1 case, we used circulatory arrest. Selective ACP was achieved with flow into the right common carotid by way of the innominate graft and directly into the left common carotid by cannulation when the arch was open, using a flow of 10 to 15 mL/kg/min. The perfusion pressure was maintained at 50 to 70 mm Hg.

Both the false and the true lumens were opened to inspect the ascending aorta and transverse arch and to identify the aortic tear. In addition, when the layers of the 2 lumens were clearly separated, a few 6-0 Prolene stitches were used circumferentially to approximate them, and Bioglue (Cryolife, Inc, Kennesaw, Ga) was applied in a thin layer. A large (30-mL) Foley catheter was then inflated for 1 to 2 minutes to allow better approximation of the false and true lumens. Total arch replacement was performed in rare cases in which either the transverse arch was clearly aneurysmal (5.5-6 cm) and the dissection was a superimposed condition or the arch was structurally destroyed. In all other cases, the ascending aorta and hemiarch were replaced with a Dacron Gelweave graft (Vascutek Ltd, Renfrewshire, Scotland). In 1 case, only the ascending aorta was replaced.

For the distal anastomosis, we used 2 layers of running 4-0 (occasionally 5-0) polypropylene sutures. Depending on the strength of the tissues, a row of pledgeted 4-0 polypropylene sutures was placed circumferentially in addition to, or instead of, the second running row. For arch reconstruction, we usually used a previously described Y-graft technique.[8] Depending on the aortic valve's morphology and function, we usually performed resuspension and/or commissuroplasty. If severe chronic disease of the valve leaflets was present, the valve was replaced. If the aortic root was enlarged or the patient was known to have a connective tissue disorder, we replaced the aortic root. Additional procedures were performed as necessary during the rewarming process (Table 3). After the temperature reached 36.5°C, the patient was weaned from CPB and given protamine.

Group B. Until October 2011, we used the GORE TAG graft (W. L. Gore & Associates, Inc, Flagstaff, Ariz) for the group B patients. Since October 2011, we have used the Conformable TAG device (W. L. Gore & Associates, Inc). We generally used an endograft 10% to 15% larger than the long axis of the true lumen of the proximal DTA. The chosen stent length was 10 or 15 cm, depending on the patient's body habitus and height. Before starting to reconstruct the distal aortic

TABLE 1. Preoperative and presentation characteristics (n = 112)

Characteristic	Group A (n = 87)	Group B (n = 25)	*P* Value
Median age (y)	57 (48-66)	64 (48-73)	.20
Male gender	63 (72.4)	22 (88.0)	.11
Smoking	50 (57.5)	18 (75.0)	.12
Hypertension	78 (89.7)	24 (96.0)	.45
Cardiac disease unrelated to aorta			
Coronary artery disease	25 (28.7)	9 (36.0)	.49
Congestive heart failure	27 (31.0)	6 (24.0)	.50
Previous myocardial infarction	7 (8.1)	5 (20.0)	.14
History of arrhythmia	6 (7.0)	2 (8.0)	1.00
NYHA functional class			
I	21 (24.1)	2 (8.0)	—
II	14 (16.1)	8 (32.0)	—
III	12 (13.8)	11 (4)	—
IV	40 (46.0)	4 (16.0)	—
Genetically triggered thoracic aortic disease*	9 (10.3)	1 (4.0)	.45
Renal dysfunction	28 (32.2)	9 (36.0)	.75
Pulmonary dysfunction	15 (17.2)	7 (28.0)	.26
Diabetes mellitus	8 (9.2)	3 (12.0)	.71
Previous stroke	6 (6.9)	4 (16.7)	.14
Significant pericardial effusion or tamponade	14 (16.1)	6 (24.0)	.38
Preoperative malperfusion	24 (27.6)†	19 (76.0)†	<.0001
Lower extremity	9 (10.3)	15 (60.0)	<.0001
Renal compromise	12 (13.8)	8 (32.0)	.07
Coronary arteries	1 (1.2)	1 (4.0)	.40
Bowel	1 (1.2)	0 (0.0)	1.00
Right common carotid artery	1 (1.2)	0 (0.0)	1.00
Preoperative malperfusion with simultaneous neurologic deficit	10 (11.5)	16 (64.0)†	<.0001
Lower extremity	7 (8.1)	14 (54.0)	<.0001
Transient ischemic attack	3 (3.5)	3 (12.0)	.12
Mental status changes on arrival	5 (5.8)	2 (8.0)	1.00
Patient intubated on arrival	7 (8.1)	4 (16.0)	.26
CPR in progress on arrival	3 (3.5)	0 (0.0)	1.00

Data presented as median (interquartile range [25%, quartile 1, to 75%, quartile 3]) for continuous variables and n (%) for categorical variables. *NYHA*, New York Heart Association; *CPR*, cardiopulmonary resuscitation. *Marfan syndrome in 5, family history in 1, genetic mutation in 2, Loeys-Dietz syndrome in 2 (group A); highly suspicious for genetic mutation in 1 (group B). †A few patients presented with more than 1 area of compromise.

anastomosis, we performed antegrade stent graft delivery as follows. After the stent was prepared, we applied a gentle manual curve to the endograft. A soft glide wire was placed antegrade, under direct vision, down the true lumen of the DTA and was then exchanged over a catheter for a stiff Amplatz or Lunderquist wire. The stiff wire was not advanced >20 cm into the descending aorta. The stent was then placed over the stiff wire and deployed just distal to the left subclavian artery. Because the body temperature was hypothermic, warm water was applied directly to the graft to facilitate full expansion. Next, one or two 4-0 or 3-0 polypropylene sutures were placed along the lesser curve of the arch to secure and conform the device. After stent graft deployment, the distal anastomosis was constructed by leaving only a small piece of native aortic tissue at the arch. Depending on the anatomy encountered, the proximal portion of the endovascular stent graft was incorporated into the distal suture line along the lesser curvature of the arch at the level of the distal aspect of the left subclavian artery. The rest of the procedure was performed as described for group A.

TABLE 2. Operative variables (n = 112)

Variable	Group A (n = 87)	Group B (n = 25)	*P* value
Repeat sternotomy	6 (6.9)	3 (12.0)	.42
Index procedure			
Proximal arch/hemiarch repair	79 (90.8)	25 (100)	.20
Total arch repair	7 (8.1)*	0 (0.0)	.35
Ascending aortic repair	87 (100)	25 (100)	1.00
Concomitant procedures			
Aortic valve repair	56 (64.4)	17 (68.0)	.74
Aortic root replacement	18 (20.7)	4 (16.0)	.78
Aortic valve replacement	4 (4.6)	4 (16.0)	.07
Coronary artery bypass	5 (5.8)	2 (8.0)	.85
Blood transfusion (red blood cells)	55 (66.3)	19 (76.0)	.36
Median operative time (min)			
Cardiopulmonary bypass	117 (95-157)	115 (94-142)	.34
Myocardial ischemia time	84 (69-110)	86 (72-123)	.95
ACP time	31 (23-39)†	30 (24-36)	.63
Total circulatory arrest time	34.5 (28-42)	35 (29-41)	.88
Surgery duration	353.5 (299-436)	345 (291-425)	.37

Data presented as median (interquartile range [25%, quartile 1, to 75%, quartile 3]) for continuous variables and n (%) for categorical variables. *ACP*, Antegrade cerebral perfusion. *Three patients underwent an elephant trunk procedure. †ACP was used in 86 of 87 patients in group A; crossclamping was used in the remaining patient.

Follow-up Evaluation

Follow-up data were obtained by consulting the hospital medical records and the Social Security Death Index and by telephoning patients or their families. Each CT angiogram was reviewed. The overall mean follow-up period was 45.5 months (range, 21.4-76.2). In Group A, it was 58.06 months (range, 38.9-80.6) for 61 patients among the survivors with complete imaging; in group B, it was 4.84 months (range, 3.0-6.7) for 20 patients.

TABLE 3. Early outcomes (n = 112)

Outcome	Group A (n = 87)	Group B (n = 25)	*P* value
30-d Mortality	12 (13.8)	3 (12.0)	1.00
In-hospital mortality	13 (14.9)	3 (12.0)	1.00
Stroke	9 (10.3)	3 (12.0)	1.00
Resolved malperfusion*	13 (54.2)	16 (84.2)	.037
Paraparesis	1 (1.5)	2 (8.0)	.24
Paraplegia	0 (0.0)	0 (0.0)	—
Acute renal insufficiency	10 (11.8)	4 (16.0)	.73
Temporary hemodialysis	6 (7.3)	2 (8.0)	—
Permanent hemodialysis	0 (0.0)	0 (0.0)	—
Reoperation for bleeding	8 (9.2)	3 (12.0)	.71
Pericardial window	6 (6.9)	2 (8.0)	1.00
Tracheostomy	13 (15.3)	4 (16.0)	1.00
Poor wound healing/dehiscence	2 (2.3)	0 (0.0)	1.00
Lower extremity amputation	0 (0.0)	1 (5.0)	.22
Median ICU stay (d)	6 (3-18)	8 (4-18)	.27

Data are reported as median (interquartile range [25%, quartile 1, to 75%, quartile 3]) for continuous variables and n (%) for categorical variables. *ICU*, Intensive care unit. *Of the 24 patients with malperfusion in group A and 19 patients with malperfusion in group B.

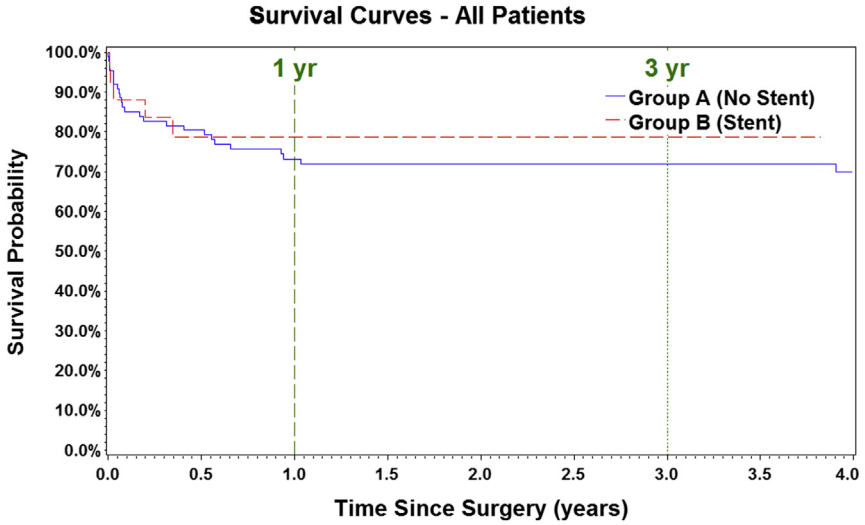

FIGURE 1. Kaplan-Meier survival curve. Log-rank $P = .64$.

Statistical Analysis

We compared the stented and nonstented patients' preoperative characteristics, presentation, operative variables, and early outcomes. Significant differences were determined using the Student t test for continuous data and the chi-square or Fisher exact test for categorical data.

Survival functions were estimated using the Kaplan-Meier method and compared using the log-rank test. Patients who did not die before the end of the study period were considered censored. We calculated the risk ratios at specific points, using the estimated rates of survival for the stented and nonstented patients. Differences between these ratios were assessed using the Yates chi-square test.

All statistical analyses were conducted using Statistical Analysis Systems software, version 9.1 (SAS Institute, Inc, Cary, NC).

RESULTS

An analysis of the preoperative characteristics showed that group B had more malperfusion and neurologic symptoms at presentation than did group A ($P < .0001$; Table 1). More patients in group B had previously undergone sternotomy (12% vs 6.9%), but this difference was not significant ($P = .42$). No intergroup difference was observed in the systemic and total circulatory arrest times or in the procedural time (Table 2). At presentation, 24 group A patients and 19 group B patients had malperfusion; the diagnosis of malperfusion was determined from the clinical findings and appropriate laboratory studies and was confirmed by radiography. After the procedure, this condition had resolved in 13 group A patients (54.2%) and 16 group B patients (84.2%; $P < .037$). The early clinical outcomes are listed in Table 3.

Mortality

In group A, 13 patients died in the hospital (14.9%), and 30-day mortality was 13.8% (n = 12 patients). The nonsurvivors included 3 patients who had been undergoing cardiopulmonary resuscitation when they entered the operating room, 3 patients who had had cardiac tamponade on presentation, 2 patients who had experienced sudden cardiac arrest, 1 patient with pre-existing advanced ischemic bowel disease, 1 patient with ongoing myocardial infarction on presentation, and 2 patients who were intubated on arrival. Among the 13 patients, 5 had unresolved malperfusion (38.5%). In group B, 3 patients (12%) died in the hospital, including 1 patient who was intubated and in extremis on arrival. No intergroup differences in mortality (Figure 1) were identified ($P = 1.00$).

Short-Term Outcomes

Intervention in distal thoracoabdominal aorta. Of the group A (nonstented) hospital survivors, 8 (10.8%) required reoperation on the distal thoracoabdominal aorta a median of 776.5 days (range, 168.5-1102.0) after the initial procedure. The false lumen of the descending and abdominal aorta was patent in 4 of these patients and was partially thrombosed in the other 4. Reoperation was required for only 1 group B (stented) patient (4.6%; $P = .68$), who underwent stent removal and an extent II replacement of a rapidly expanding thoracoabdominal aneurysm on day 54. The aneurysm's false lumen was partially thrombosed (Table 4). All other aortic procedures are listed in Table 4. No type Ia endoleaks were encountered.

Fate of the false lumen. In both groups, the false lumen remained patent in almost one half of the surviving patients with follow-up data available (51.8%; n = 42). The false lumen was partially thrombosed in 27 (44.4%) group A patients and 8 (40%) group B patients ($P = .8$; Table 4). It was completely thrombosed in 2 group A patients (3.3%) and 2 group B patients (10%). Of the survivors with a patent false lumen or partially thrombosed false lumen, 4 (9.5%) and 5 (14.3%), respectively, underwent an intervention in the distal thoracoabdominal aorta ($P = .5$).

TABLE 4. Secondary aortic procedures and fate of the false lumen among the survivors

Variables	Group A	Group B	*P* value
Secondary procedures*			
DTA and TAA			
Total	8 (10.8)	1 (4.6)	.68
Endovascular procedures (TEVAR)	2	0	—
Open thoracoabdominal aortic repair	5	1	—
Open descending thoracic aortic repair	1	0	—
Other aortic procedures			
Total	3 (4.1)	1 (4.6)	1.00
Left coronary artery button pseudoaneurysm	1	0	—
Redo ascending and AVR	1	0	—
Pseudoaneurysm of ascending aorta, redo (×2) sternotomy	1	0	—
Arch repair, redo sternotomy for arch aneurysm	0	1	—
Extra-anatomic bypass and endovascular exclusion of arch for arch aneurysm	0	1	—
Fate of false lumen†			
Patent false lumen	32 (52.5)	10 (50)	1.00
Partial thrombosed false lumen	27 (44.3)	8 (40.0)	.80
Completely thrombosed false lumen	2 (3.3)	2 (10.0)	.25

Data presented as n (%). *DTA*, Descending thoracic aorta; *TAA*, thoracoabdominal aorta; *TEVAR*, thoracic endovascular aneurysm repair; *AVR*, aortic valve replacement. *Total patients, n = 74 for group A and n = 22 for group B (hospital survivors). †False lumen patient total, n = 61 for group A and n = 20 for group B (survivors with follow-up data).

DISCUSSION

Many different interventions for DeBakey type I aortic dissection have been described with regard to the extent of proximal aortic surgery, including ascending aortic replacement with crossclamping versus open distal repair with hemiarch or full arch replacement. Because of the technical and practical advantages—avoidance of crossclamp damage, resection of the primary entry tear (especially when it extends deeper into the arch), and more complete resection of the ascending aorta—many groups have adopted ascending aortic and hemiarch replacement in the surgical treatment of proximal aortic dissection.[2,4,9-11] More extensive arch replacement has also been advocated by a few surgeons in an attempt to decrease the rate of late reoperation on the distal aorta.[12,13] With these strategies, the 5-year freedom from reoperation on the distal aorta has varied from 66.7% to 95.7%.[3,13] It has been our practice to proceed with open distal anastomosis during repair of acute type I aortic dissection. We are aware that controversy exists regarding the clinical effects of the different modes of ACP delivery (unilateral vs bilateral) and the safe limits of circulatory arrest with warmer temperatures despite the use of ACP. In our practice, cerebral protection for open distal repair has been achieved with systemic hypothermia to 24°C and bilateral ACP, when feasible. The present study was not intended to evaluate the different delivery methods of ACP or the effects of various temperatures on the outcomes.

In the series reported by DeBakey and colleagues,[14] which involved 527 patients followed up for 20 years, 57% of the patients survived for 5 years. Among those who succumbed to late death, rupture of the distal aorta was the main cause (29.3% of cases), and in 23% of those cases, the aortic diameter was <6 cm.[14] In addition, the incidence of aneurysm formation was approximately 30% if the dissection had extended into the entire DTA but only 14% if the dissection was limited to the ascending aorta. The same dismal 55% 5-year survival rate was observed by the Stanford group for patients with acute type I aortic dissection, in whom older age and previous surgery significantly predicted late death.[15] Mani and colleagues[16] described 50 patients who were followed up for aneurysms in the DTA secondary to chronic dissection; of the 10 patients who underwent surgical intervention, 9 died of rupture during the 40-month follow-up period.

To decrease the risk of malperfusion, late distal reoperation, and aneurysmal degeneration and rupture, a hybrid approach to type I aortic dissection has recently been reported.[17-19] From these results, our approach to treating acute type I aortic dissection has become more creative with the implementation of new technology. In mid-2009, we started selectively using the hybrid approach for proximal dissections that extended into the aortic bifurcation. Before then, we repaired all type I aortic dissections using the traditional approach, performing ascending and hemiarch replacement with or without full arch replacement.

In the present series, the patients in group B were "much sicker," with more patients who presented with malperfusion and neurologic deficits than in the traditionally treated group (group A; $P < .0001$). In addition, malperfusion had resolved after the procedure in 84.2% (all but 3) of the patients in group B versus 54.2% in group A ($P < .037$). The hybrid component did not increase the total circulatory arrest time ($P = .88$) or the total procedural time ($P = .37$). Our experience with stent graft delivery for patients with acute type III aortic dissection and our experience with hybrid aortic arch surgery helped us keep the circulatory arrest time and total procedural time comparable between the 2 groups. In addition, the same cardiovascular team performed the repair of the type I aortic dissection and the stent graft delivery. The necessary wires, catheters, and stent grafts were prepared before circulatory arrest was initiated, and the decision to proceed with the hybrid repair was made before surgery.

The stent used in our hybrid procedures was delivered antegrade during circulatory arrest, as reported by other investigators.[18,19] In adding this hybrid step to the traditional repair of acute aortic dissection, our aim was

to perform the additional step safely, using a simple and reproducible method, without adding significant time to the overall procedure. Hofferberth and colleagues[17] reported retrograde delivery of such a stent graft, which was initiated on sternal closure. Gentle advancement of the balloon along the entire length of the stent without using a guide wire has been described by Pochettino and associates.[19] We delivered the stent over a guide wire placed into the true lumen under direct vision. In advancing the wire distally, it is theoretically possible for it to traverse into the false lumen, a problem we have not encountered.

The stents used in these series were 10 or 15 cm long and therefore unlikely to extend beyond T7 or T8. Perhaps for this reason, no permanent spinal cord ischemia was noted in group B. It is true that if paraplegia is not present before an acute type I aortic dissection is repaired, it is rarely encountered afterward. Therefore, we are very cautious about extending the coverage of the DTA to the celiac level. No specific algorithm was used to decide which graft length to use (10 or 15 cm). Body habitus, height, and preoperative planning to avoid extensive descending thoracic aortic stent coverage were the main reasons we used these stent lengths. We did not use a balloon, because doing so during the acute phase of the dissection would endanger the friable wall between the true and false lumens. After the stent has been deployed under circulatory arrest, we use a bulb syringe to put warm water directly into the stent, which expands immediately. The stent would be expected to continue to expand under normothermic conditions as the rewarming process takes place after completion of the distal anastomosis. We did not encounter any instances of inadequate stent expansion in the present study.

Regarding the selection of the stent device, the GORE TAG graft was used in all our patients until the Conformable TAG device was introduced in late 2011.[19,20] Other devices have reportedly been used for this purpose; however, we remain concerned about using open wire in such cases, as described by others.[17,18] With the described technique, we do not believe that more extensive aortic arch repair is necessary. The only native aortic tissue left in the arch is a small, almost V-shaped remnant of aortic tissue at the greater curvature of the aortic arch, which includes the innominate and left common carotid arteries. We proceed with total arch replacement if the arch is aneurysmal, with extensive dissection that cannot otherwise be repaired. Our group has previously reported, on the basis of the operative experience of Dr Crawford, that the mortality risk increases in surgery for acute dissection when the replacement involves both the entire arch and the ascending aorta.[21]

The published data have supported obliterating the false lumen to limit the future growth of the dissected aorta and the risk of reoperation. The patency of the false lumen strongly influences aortic enlargement in patients who undergo traditional repair of acute type A aortic dissection.[22] Kimura and colleagues[22] showed that most patients with a thrombosed false lumen have slight or no aortic enlargement. Although debate exists regarding the significance of a partially thrombosed false lumen as a risk factor for aortic enlargement, most reports have associated such thrombosis with poor long-term survival.[23-25] We found no evidence for a partially thrombosed false lumen as a risk factor; furthermore, we observed no remodeling of the DTA after antegrade stent placement. One possible explanation for the nonremodeling of the aorta and the nonthrombosis of the false lumen among many group B patients was the relative short period of follow-up. None of our patients with a completely thrombosed false lumen underwent aortic intervention in the descending or thoracoabdominal aorta.

The present study was limited by its retrospective nature, the relatively small number of patients in the hybrid group, and the paucity of complete follow-up data, especially for the traditional surgical group. Despite the study limitations, these results have increased our enthusiasm regarding this technique and its potential benefits.

CONCLUSIONS

Hybrid repair of acute type I aortic dissection with antegrade stent graft delivery in the DTA is feasible and safe, does not affect short-term mortality, and does not increase the circulatory arrest time for the procedure. The false lumen remained patent in the short term despite stent grafting of the DTA. This evolving technique could benefit patients who present with malperfusion. Additional studies and long-term follow-up are needed to confirm the potential value of this approach.

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